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DOUGLAS FIR:

A STUDY OF THE PACIFIC COAST AND ROCKY MOUNTAIN FORMS.

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DOUGLAS FIR.[a]

Pseudotsuga taxifolia (Lam.) Britton.

A STUDY OF THE ROCKY MOUNTAIN AND PACIFIC COAST FORMS.

INTRODUCTION.

No other important commercial tree in America is so widely distributed as Douglas fir, and it is safe to say that none which has been introduced into Europe has attracted so much attention among foresters there. The immense size which it attains in portions of its range, its high commercial value, rapid growth, and, above all, the ease with which it lends itself to silvicultural management and to forest planting in many kinds of situations, all combine to place it among the most useful of the world's forest trees. Great inroads have been made on the existing stands of Douglas fir, but under the conservative policy now being applied on the National Forests there is little danger that the tree will ever cease to be an important part of the forests within its range.

The exploitation of Douglas fir is enormous. The census of the lumber cut in the United States during 1907 shows that it was second only to the eastern "yellow pine"—a commercial name which includes at least five distinct species. In the western United States the cut of Douglas fir—4,748,872,000 board feet—was more than three times as great as that of its closest competitor, western yellow pine. Nearly 95 per cent of this was cut in Washington and Oregon, where Douglas fir comprised 82 and 84 per cent, respectively, of all the lumber cut in those States. In California Douglas fir was outclassed only by redwood and western yellow pine. Throughout the Rocky Mountains the Douglas fir cut was exceeded by that of western yellow pine; in Wyoming, Arizona, and New Mexico it held second place, and in

[a] The Forest Service is indebted to Mr. John D. Crozier, forester of the Durris estate, Drumoak, Aberdeenshire, Scotland, for permission to include in this circular the illustrations on pages 8 and 10, the originals of which appeared in his article on "Douglas Fir as a Commercial Timber Tree," in Transactions of the Royal Scottish Arboricultural Society, vol. 21, pt. 1, January, 1908.

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Montana, Colorado, Idaho, and Utah third. In 1907, 139,315,000 board feet of Douglas fir were cut in the Rocky Mountains, which constituted 11.5 per cent of the total cut for this region. The percentage was lowest (0.5 per cent) in Arizona, and, strangely enough, next to the highest (13.2 per cent) in the adjoining Territory of New Mexico.

According to a recent estimate,[a] there is still standing in Washington, Oregon, California, Idaho, Montana, and British Columbia 374,064,102,000 board feet of Douglas fir. Western yellow pine stands second, with 175,586,520,000 board feet. Giant arborvitæ is third, redwood fourth, hemlock fifth, and sugar pine sixth.

The qualities for which Douglas fir is prized vary considerably in different parts of its range. In Washington and Oregon, where it attains its largest dimensions, its size, strength, durability, clearness, and straightness of grain make it an excellent timber for bridge building and general construction. In the Rocky Mountains its durability in contact with the soil adapts it primarily for mine timbers and railroad ties, in which clearness and length are not requisite. So much Douglas fir is used in the rough for these purposes that the census figures, which are for lumber cut only, do not indicate the importance of Douglas fir compared with other species in the Rocky Mountains.

HISTORICAL.

Douglas fir was discovered by Archibald Menzies at Nootka Sound, Vancouver Island, in 1792, during the voyage of Captain Vancouver. It was introduced into Europe by the Scotch botanist, David Douglas, who obtained the seed in the State of Washington and took it to England in 1827. Since that time it has been planted with great success in Scotland and in many parts of continental Europe, where it is highly valued for its rapid growth, hardiness, and the quality of its wood. Up to about 1870 practically all the seed taken to Europe came from the fir forests of the northwestern coast of the United States. Since that date seed has been taken into Europe from Colorado, where Douglas fir was found growing on the eastern slopes of the Rocky Mountains by Doctor Parry in 1861.

Douglas fir was first described in 1803 under the name of *Pinus taxifolia* by Lambert, who did not know that in 1796 balsam fir (*Abies balsamea*) had been given this name by Salisbury. It was later renamed no less than four times by various botanists, some of whom assigned it to the genus *Pinus*, some to the genus *Abies*. In 1867 Carriere separated it into a new genus, which he named *Pseu-*

[a] Pacific Lumber Trade Journal, January, 1907.

dotsuga—from *pseudo*, the Greek word for false, and *tsuga*, the Japanese word for hemlock. He adopted the specific name *douglasii*, in honor of David Douglas, which has since been almost universally employed in Europe for this tree. *Pseudotsuga taxifolia*, the technical name now used in the United States, was proposed in 1899 by Britton, following the commonly accepted law of priority, by which the specific name *taxifolia*, first published by Lambert in 1803, has precedence over all subsequent specific names.

In this country Douglas fir is popularly known by a great number of different names. Some of the most common are red fir, yellow fir, Oregon pine, red pine, red spruce, and Douglas spruce. The name red fir is very extensively used, particularly on the Pacific coast, where trees with red wood are known as "red fir" and those with yellow wood as "yellow fir." The name "Douglas fir" was adopted by the Forest Service, following a lumber census in which this name was used more than all others combined.

DISTINGUISHING CHARACTERISTICS.

In many respects Douglas fir resembles the spruces, hemlocks, and true firs or balsams. Like them, its leaves are arranged singly along the twigs, usually comblike, and not in clusters, as they are in the larches or tamaracks and in all the pines except single-leaf piñon. In this respect also it differs from cedar, juniper, and cypress, which have their leaves pressed together like scales. Though its leaf arrangement might cause it to be confused with hemlock, balsam, or spruce, it has other characteristics by which it may be distinguished with certainty from each of these.

While its flattened leaves and the resin blisters of its young bark cause it to resemble the balsam firs, it differs from them in its cones. These are pendant and fall off entire, without breaking up into scales, and can also be easily distinguished from those of most balsam firs by their long, protruding, three-pointed bracts, which give them a characteristic "feathered" appearance. Douglas fir is a prolific cone producer, and cones can nearly always be found on its branches or on the ground under the tree. A further distinction lies in the attachment of the leaves; in Douglas fir the leaves have a slight stalk, while in the balsams they are sessile. The bark of mature trees and the wood structure, as well as the shape of the tree, are also sure means of distinction when once they have been compared.

Douglas fir resembles the spruces in its pendant cones, but differs from them in having the cones "feathered." It is also distinguished unmistakably from the spruces by its flattened leaves, which will not

roll between the fingers, its young bark, smooth and with resin blisters, the shape of the tree, and its wood structure.

It resembles hemlocks in having flat, petioled leaves, but differs from them in the larger size of its cones and in their protruding bracts. The wood often has a slight resemblance to that of hemlock in its grain, but it is highly resinous, while hemlock wood is without resin.

Douglas fir can be distinguished with certainty from all other conifers except its close relative, bigcone spruce, by its sharp-pointed, conical buds, which are a bright red-brown when mature. It also differs in the form of its upper crown from most other conifers with which it is associated. Its relatively long top branches are inclined upward, and form an ovate, obtusely pointed crown, very different from the narrow, spire-shaped tops of balsam and spruce, and the open crowns of the pines. The foliage, which is retained on the branches for a distance of from 8 to 11 years' growth from the tip, is somewhat lighter and less compact than that of balsam or spruce.

The bark varies greatly with age. In youth it is smooth and white, with numerous resin blisters. With advancing age it becomes scaly at first and then gradually breaks up into ridges, separated by deep furrows. At the same time it deepens in color, from light gray to a very dark gray-brown. In cross-section it is composed of a cinnamon-brown body, broken up into scales by intersecting narrow streaks of a lighter brown. The bark of mature trees shows regional variations in character, and in some localities, notably the Uinta National Forest, remains scaly for a much longer time than in others, and never becomes so deeply ridged as usual.

The root system of Douglas fir accommodates itself readily to local soil conditions. On deep, sandy loams it develops a central division of two or three strong roots which penetrate deeply into the earth, and at the same time sends out numerous relatively shallow lateral roots. On shallow soils it develops a flat, spreading root system, but penetrates into rock crevices and loose soils with a strong taproot. In dense stands the root system is shallower and smaller compared with the height of the tree than in the open, so that the danger from windfall is great after heavy thinnings.

The only species for which Douglas fir lumber is apt to be mistaken are the hard pines and larch. Like these, it produces a strong, hard, pitchy wood, especially characterized by broad bands of dark-colored summer wood in the annual rings; but it is more variable in its diameter growth than these species, and the yearly rings may be narrow, with very little of the brown summer wood, or broad, with nearly as much summer wood as spring wood. It also differs from

them in the proportions of heartwood and sapwood, and usually has a greater proportion of the former than yellow pine.

SILVICAL FORMS.

With a range extending over more than 2,000 miles from north to south and almost 1,000 from east to west, Douglas fir grows under more diverse climatic conditions than any other important American timber tree. In various parts of this range it produces forms of growth sufficiently diverse, in the opinion of some foresters, to be called varieties, or even species. Whatever its botanical status, it is certain that in its silvical characteristics and requirements Douglas fir presents two well-marked forms.

These may be contrasted as the form of *best development* and the form of *best resistance*. The first is well defined on the Pacific coast, where conditions are favorable for rapid growth to its largest size; the other in the Rocky Mountain region, where less favorable climatic influences limit its rate of growth and size. In the moderately humid climate of northern Idaho and northwestern Montana the two forms seem to intergrade and the tree reaches a large size in moist situations at low altitudes, but is smaller in drier places and at higher elevations. Different methods of silvicultural treatment are required for the two forms, partly by the widely varying nature of the forests in which they grow and partly by the different natures of the trees themselves.

VARIATIONS BETWEEN THE COAST AND MOUNTAIN FORMS.

The differences between the Rocky Mountain and coast forms of Douglas fir are both physiological and morphological. They include variations not only in rate of growth and sensitiveness to frost, but also in the form of the tree, the size and shape of the cones, the character of the foliage, and even the grain of the wood. Many of these differences are in themselves insignificant, but when both forms are raised side by side from the seed the cumulative effect is very striking.

The most apparent of these variations is in the rate of growth. In the German forest experiment station at Grafrath, 17-year-old trees of the coast and Rocky Mountain forms which were grown together in the same soil reached average heights of 26 and 7.5 feet, respectively. At Groenendael 13-year-old trees of the coast form averaged 21 feet in height and 3⅓ inches in diameter, while 12-year-old mountain firs growing beside them were only 9⅔ feet high and less than 1⅔ inches in diameter. In a 7-year-old Scotch plantation a typical specimen of the mountain form was 8 feet 10 inches high, while a tree of the coast form, standing 4 feet away, had attained a height of 15 feet 6 inches (fig. 1).

FIG. 1.—Specimens of Rocky Mountain and coast forms of Douglas fir, from a plantation 7 years old. The mountain form was 5 years old when planted, and the coast form 3 years old. Their heights are: Mountain form, 8 feet 10 inches; coast form, 15 feet 6 inches.

This difference in rate of growth is attended by a corresponding difference in the form of the young trees. The rapid-growing coast fir produces long, slender branches, at relatively wide intervals on the main trunk. They leave the stem at a rather acute angle, but are often gradually curved by their own weight toward a horizontal position. The mountain form has shorter, comparatively stiff branches, which are closer together and tend to maintain the direction in which they start from the trunk. The compact, upright crown of the mountain fir and the more open, drooping appearance of the coast form are contrasted in figure 1.

The more rapid growth of the coast form is achieved partly by the production of a second "leader," or main growing shoot, in the autumn, while the growing season of the Rocky Mountain form comes to an end earlier in the year. The early termination of its growth period allows the Rocky Mountain form to harden its wood before the first severe frosts, an advantage which is lost to the coast fir, with its succulent autumn shoot. This characteristic prevents the cultivation of the otherwise more desirable coast form in some places.

In Europe the terms "green" and "blue" Douglas fir are often applied to the coast and mountain forms, respectively, because the leaves of the former are dark green, while those of the mountain form are often bluish like the foliage of blue spruce (*Picea parryana*). This blue tint is not constant, however, and may be very pronounced in some specimens and entirely absent from others in the same locality.

The size, shape, and structure of their cones also distinguish the two forms (fig. 2). The cone of the Rocky Mountain fir is smaller, fewer-scaled, and more evenly conical than that of the coast fir. Its bracts project more, and are strikingly reflexed, often standing out at right angles from the cone-axis. Cones of the coast fir are from $2\frac{1}{2}$ to $4\frac{1}{2}$ inches long and about 1 inch broad, while those of the mountain form are rarely over 3 inches long, though they often have a breadth of 1 inch.

Though no distinction has as yet been made on the basis of the minute structure of the wood, lumbermen who have sawed both forms testify to the difference between them in grain and in ease of working. Pacific coast lumbermen have, furthermore, always divided the coast form into two kinds, "red" and "yellow" firs. "Yellow" fir commands a price of at least a dollar more per thousand feet, board measure, than "red" fir. The difference is due mainly to rate of growth. In the humid coast climate, trees in dense stands grow rapidly in height, but slowly in diameter, and the fine-grained, light, yellowish wood which results is "yellow" fir. In more open stands, with more light, diameter growth is faster, and the wider rings con-

tain more of the dark-colored, flinty summer wood, which gives the name "red" fir. Since trees ordinarily grow most rapidly in youth and fall off with advancing age, "red" firs are apt to become "yellow" firs as they grow older and the annual rings become narrower. In old trees the rings are wider near the top than at the stump, and old "yellow" firs are thus often found which contain red wood at the center and top while the rest of the wood is yellow. Slight differences in the texture of the bark, which accompany this

FIG. 2.—Cones of the Rocky Mountain and coast forms of Douglas fir. The cone of the former is smaller and more evenly conical, and has its bracts more projecting and reflexed.

difference in rate of growth, often make it possible to distinguish in the forest between "red" and "yellow" firs.

The mountain form exhibits no such difference, but although it is often of slow growth it produces a red wood, with usually a large proportion of summer wood. It is neither as straight-grained nor as easily worked as the coast fir, but is highly valued for its strength and its durability in contact with the soil, in which respects it surpasses the other species with which it grows.

GEOGRAPHICAL DISTRIBUTION.

The coast form of Douglas fir grows in the coast ranges from the head of Skeena River, in British Columbia, southward through Washington and Oregon, and into California as far as the Santa Lucia Mountains. It also grows along the Cascade and Sierra Nevada mountains in these States to the headwaters of the San Joaquin River, in Fresno County, Cal. The tree is of extremely rare occurrence on the eastern slopes of this mountain chain, however, from the southern extreme of its range to almost as far north as Mount Hood, in Oregon. Its region of best development and greatest abundance is in Washington and northern Oregon, west of the Cascade Range. It reaches almost as large dimensions, however, under the favorable climatic conditions offered by the humid western slopes of the northern Sierra Nevada Mountains as it does on Puget Sound. In dry situations in the Sierras its development resembles that of the mountain form.

The mountain form grows throughout the Rocky Mountain system from Tacla Lake, British Columbia, latitude 55° north, southward for at least 2,200 miles. It is absent or rare in the dry interior basins and on the semiarid plateaus and minor mountain spurs lying between the principal ranges, especially toward the southern and eastern limits of its range. It is entirely absent from the high plateau region of Nevada. In the drier parts of the Rocky Mountains, especially in the south, it is confined almost exclusively to high elevations.

RELATION OF ALTITUDE TO DISTRIBUTION.

From north to south both forms of Douglas fir occupy progressively higher situations in the mountains. This results from their demand for a certain amount of moisture in soil and air, which is found at higher altitudes in the south than in the north. As a general rule, the mountain form of Douglas fir grows at a higher elevation above sea level than the coast fir in the same latitude. This also is due principally to moisture conditions, which are more favorable to its growth at lower altitudes near the coast than in the mountains. Where competing species are not influential in restricting its altitudinal range its limits are climatically defined—below by lack of moisture, and above chiefly by low temperature and shortness of the growing season.

The coast form grows in the Olympic Mountains in Washington from sea level to an altitude of 3,500 feet, and in the Cascades from the lowest elevations to 6,000 feet. In Oregon it grows in the Coast Range between sea level and 6,200 feet, and is sometimes found in the Cascades at an altitude of 7,200 feet. In the California coast moun-

tains its lower limit is considerably above the sea. In parts of the Klamath and Trinity National Forests it grows as low as 900 feet above sea level, but is apt to be scrubby and scattered up to 2,000 feet, while none of its scant representation in the Santa Lucia Mountains is found below 2,500 feet. On the western slope of the Sierra Nevada Mountains it is sometimes found in river valleys as low as 800 or 900 feet above sea level, but is usually scattered and stunted below 2,000 feet, and reaches its best development between altitudes of 3,000 and 6,000 feet, while in Mariposa County, near the southern limit of its range, it grows, more or less stunted, up to 7,500 feet.

The mountain form at its northern limit, near Tacla Lake, in British Columbia, grows at an elevation little over 2,000 feet, which is about the common level of the country. In Idaho, Montana, and northern Wyoming it is found at altitudes of between 2,400 and 9,000 feet; in southern Wyoming, northern Colorado, Utah, and northern Nevada, between 6,000 and 9,000 feet; and in southern Colorado and Utah, Arizona, New Mexico, and western Texas, between 7,000 and 11,000 feet above the sea. At the extremes of altitude, especially in the south, the growth consists chiefly of straggling individuals, and at the highest elevations the trees become very much gnarled and stunted. Good development is usually confined to favorable localities within a narrow range of 1,000 or 1,500 feet about midway between the extremes.

RELATION OF EXPOSURE TO DISTRIBUTION.

Douglas fir is less exacting in regard to exposure than Engelmann spruce, alpine fir, and other species with which it associates, but nevertheless, in common with all tree growth, it reaches better development, in the arid portions of its range, on northern exposures than on southern, especially at low altitudes, since the more shaded northern slopes offer more moisture. This is particularly true of the Rocky Mountain form in its extension through the mountains of the Southwestern States and northern Mexico. In the north and at high altitudes throughout its range, however, where the question of moisture is not so pressing, and where trees may even be forced to the southern exposures by frosts and cold winds, Douglas fir is found on the warmer southern slopes. In such situations the growing season may be considerably longer on the southern sides of mountains than on the northern.

The coast form grows, as a rule, at lower elevations on the western sides of mountain ranges than on their eastern slopes, owing to the influence of moisture-laden winds from the sea. Especially in the southern portions of its range, Douglas fir of both forms grows best and reaches its lowest altitudinal limits in sheltered situations, such as protected canyons, slopes, and benches.

SILVICAL REGIONS WITHIN THE RANGE OF DOUGLAS FIR.

The range of Douglas fir may be divided into five silvical regions, according to the preponderance in the forest of the many different

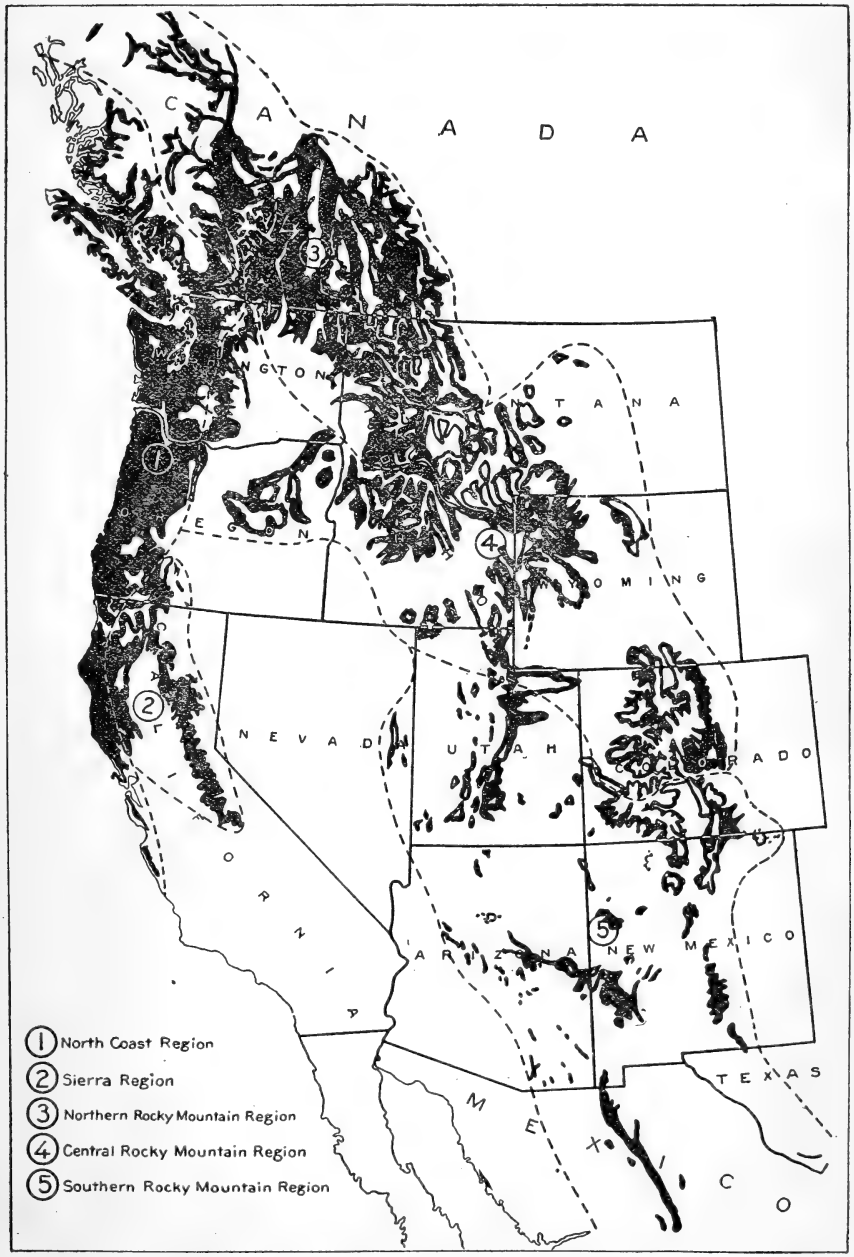

FIG. 3.—Distribution and silvical regions of Douglas fir.

species with which it is associated. These regions are the north coast region, the Sierra region, the northern, the central, and the southern Rocky Mountain regions. (Fig. 3.) The first two embrace the range of the coast form of the tree and the last two that of the mountain form. The northern Rocky Mountain region may be called a transition district in which the two forms very probably intermingle.

Though well defined at the geographical extremes of the Douglas fir range, the regions merge into one another in other parts. Each region may be further divided into local and altitudinal forest types, but each has characteristics sufficiently pronounced to distinguish it as a whole from the others. Climate is the factor fundamentally responsible for these variations in forest composition.

NORTH COAST REGION.

The north coast region extends from the crest of the Cascade Mountains, in southern British Columbia, Washington, and Oregon, to the sea, and southward to moist localities in the California coast ranges. In the exceedingly humid climate and moist soils of this region all trees reach large size, and Douglas fir attains its best development in size and abundance. About half of the heavy forests in this region are Douglas fir, which often forms extensive and practically pure stands of great density. Its chief associates are western and black hemlocks, Sitka spruce, giant arborvitæ, western white pine, and lowland, amabilis, and noble firs. Of these, western hemlock deserves the most attention because of its abundance and aggressiveness in reproducing under Douglas fir and with its heavy foliage excluding the latter from the forest. On the coast of southern Oregon and northern California the great redwood type of forest is predominant.

Modified by the prevailing warm sea winds and protected by the Rocky mountains and the Cascades from northeastern cold waves, the climate of the north coast region is generally mild and uniform, with frequent fogs and gradual and moderate changes in temperature. The summers are cool and the winters mild, with an interval of six or seven months between killing frosts. In the northern part of this region rainfall and elevation are indirect rather than direct agents in limiting the distribution of Douglas fir. The more exacting species with which it associates are able to exclude it from the more moist situations to relatively dry places, where it can compete successfully with them. This does not mean that Douglas fir is unable to thrive in moist localities provided the drainage is good, for its best development is made where rainfall is heaviest. Near sea level west of the Olympics, and from 1,500 to 2,500 feet above the sea on the western

slope of the Cascades, Douglas fir grows largest and densest, though it is often outnumbered in the forest by western hemlock, arborvitæ, and Sitka spruce. Here the annual rainfall is from 60 to more than 100 inches, three-fourths of which falls in the "wet season," from November to April, inclusive.

In western Oregon Douglas fir forms nearly 80 per cent of the forest, and its principal associates are usually Sitka spruce close to the coast and giant arborvitæ and western hemlock farther inland. On the coast of southern Oregon and northern California Douglas fir is mixed with Port Orford cedar and redwood.

An average stand of Douglas fir in this region is from 35,000 to 60,000 feet per acre, and stands have been found occasionally which would run from 150,000 to 250,000 feet per acre. South of Crater Lake, in Oregon, the forest form of this region gradually passes over into that of the Sierra region.

SIERRA REGION.

The Sierra region includes the range of Douglas fir in the Sierra Nevada, the southern extremity of the Cascades, and parts of the cross ranges of southern Oregon. It is characterized by the prevalence of sugar and yellow pines, incense cedar, and white fir mixed in varying proportions with Douglas fir. Large pure Douglas fir stands are rare in this region, and the drier conditions in which the tree grows, as compared with its range farther north, make the forest more open than in the north coast type. In these forests Douglas fir is secondary in commercial importance to the pines. In the northern and western portions of this region the forest grades into that of the north coast region. Near the southern extremity bigtree forms an important part of the forest. South of the range of Douglas fir in California it is represented by another species of the same genus, bigcone spruce, which closely resembles it in form but not in silvical characteristics.

In this region Douglas fir finds a mild, humid climate with moderate daily and seasonal ranges of temperature. The growing season is long. There is usually a rainy and a dry season, the latter of about three months' duration, from July to September. The annual rainfall varies between 20 and 60 inches. In this climate Douglas fir grows rapidly in protected situations, and attains a size nearly equal to that of the north coast fir.

NORTHERN ROCKY MOUNTAIN REGION.

The northern Rocky Mountain region includes part of southern British Columbia, northeastern Washington, northern Idaho, and northwestern Montana. In its relatively humid climate, as compared

with that farther south, several species typical of the Pacific coast meet the Rocky Mountain trees, and a great diversity in the composition of the forest is the result. The coast species, which here extend eastward to the Rocky Mountains, are western white pine, giant arborvitæ, lowland fir, western hemlock, and probably the coast form of Douglas fir. Associated with them, either as separate types or in mixture, are yellow and lodgepole pines, Engelmann spruce, alpine fir, and the Rocky Mountain Douglas fir, all of which attain their greatest importance in the Rocky Mountains.

The most characteristic forest types in this region are an alpine fir type, a white pine type, a lodgepole pine type, and a yellow pine type.

The alpine fir type occupies upper slopes and high ridges, and hence is not continuous. It is composed chiefly of alpine fir, with white-bark pine, Engelmann spruce, and, near its lower limits, a mixture of Douglas fir, lodgepole and western white pines, western larch, and aspen. The stand is open and parklike at high altitudes, but becomes dense as it descends, and gradually changes into the next type.

The white pine type occupies protected situations and moist soils with heavy stands of western white pine mixed in widely varying proportions with western larch, giant arborvitæ, Douglas fir, lodgepole pine, lowland fir, and western hemlock. Lowland fir is often a serious menace in this type through its aggressiveness in restocking burns to the exclusion of more valuable trees. Western larch predominates over limited areas, and in many places forms an important type.

The lodgepole pine type is doubtless in most cases a temporary type which has succeeded western white pine after fires, and will eventually revert to white pine or other more tolerant species if fires are kept out. The young stands are dense and crowded, but as they mature they become more open. The forest is largely pure lodgepole pine, especially on poor, shallow soils; but with deep and moist soils there is often a large proportion of Douglas fir, lowland fir, larch, and Engelmann spruce in mixture.

The characteristic yellow pine type is an open, pure forest of yellow pine and occupies relatively dry situations at low altitudes. In moist localities, however, the forest becomes dense and contains Douglas fir, lowland fir, western larch, and lodgepole pine in mixture. In swampy situations at low altitudes there is often a "cedar swamp" type, composed of giant arborvitæ, either in pure stands or in mixture with white pine, larch, hemlock, Douglas fir, or lowland fir.

The climate of this region is humid, with abundant precipitation during the growing season, sometimes as much as 40 inches. Daily and seasonal ranges of temperature are not, as a rule, excessive, and

seasonal extremes of 90° and —25° F. are rarely exceeded. The growing season is shorter than in either the north coast region or the Sierra region, but longer than in the country farther north. Killing frosts sometimes occur in July and August. Snowfall is not extremely heavy, but during the winter there are occasional prolonged periods of intense cold.

CENTRAL ROCKY MOUNTAIN REGION.

The central Rocky Mountain region is characterized by the predominance of the lodgepole pine type. This forest type is best developed in Wyoming, southern Idaho and Montana, and northern Colorado and Utah. The eastern slope of the Cascades in Washington and the mountain ranges of northeastern Oregon also belong to this region by virtue of their very similar climates and the general character of their forests.

Here, as elsewhere, altitude divides the forest into distinct types. The most generally distributed types in this region are as follows, beginning with the highest: An alpine type of Engelmann spruce, alpine fir, and other less important alpine trees, becoming in the lower portions a nearly pure spruce forest of considerable commercial importance; a lodgepole pine type, covering whole watersheds with pure, unbroken stretches of lodgepole pine, interspersed with occasional small pure and mixed stands of Douglas fir; a Douglas fir type, sometimes in extensive pure stands, but more often mixed with lodgepole pine, Engelmann spruce, and alpine fir above, and with yellow pine below; and a lowland type of yellow pine. Besides these there are large, even-aged, pure stands of aspen, which comes in densely on fresh soils after burns. The competition between lodgepole pine and Douglas fir is decided chiefly by soil moisture. Douglas fir mixes with yellow pine in the moister parts of the lowland type, displaces lodgepole pine on drier soils of the intermediate type, and mixes in the alpine forest wherever, as on burned areas, it receives light enough to cope successfully for a generation or two with the more tolerant spruce and balsam. In the mountains of northeastern Oregon and along the eastern slope of the Cascades other species, notably lowland fir and western larch, form a considerable portion of the stand.

In this region daily and seasonal ranges of temperature are great, precipitation is small or moderate, and the vegetative season is often less than three months long. The winters are long and severe, with heavy snowfall and frequent periods of extreme cold, during which the temperature sometimes falls to —30° or —40° F. The summers are hot, and in some parts of the region very dry. The annual pre-

cipitation in the Douglas fir zone is from 15 to 25 inches, largely in the form of snow. In general, snow falls more heavily on the western than on the eastern sides of the mountains.

SOUTHERN ROCKY MOUNTAIN REGION.

The southern Rocky Mountain region takes in that part of the range of Douglas fir south of central Colorado and northern Utah. It differs from the northern Rocky Mountain region in the absence of lodgepole pine as an important associate, in the great predominance of the yellow pine type, and in the presence of white fir, and, in the extreme south, of Arizona cypress and Mexican white pine. Altitudinal forest types, determined principally by moisture, include a woodland type at the lowest elevations, composed of piñons, junipers, scrub oaks, mountain mahogany, and other drought-enduring chaparral species; a yellow pine type in somewhat moister soils above this; next a fir type, principally Douglas and white firs, mixed with yellow pine, which these firs replace wherever they can obtain enough moisture; and an alpine type, which gradually replaces the fir type at high altitudes on northerly exposures and is made up of Engelmann spruce, alpine and Arizona cork firs, and limber pine. Aspen is more abundant in this region than in the northern Rocky Mountains, and is a useful associate of Douglas fir, since it is exceedingly active in restocking burns, where its light foliage produces ideal light and moisture conditions for an undergrowth of Douglas fir.

In the northern part of this region the climate is similar to that of the central Rocky Mountain region. Farther south, however, it becomes more moderate, with a longer growing season, smaller range of temperature, and heavier precipitation; in the Gila National Forest, New Mexico, the precipitation within the altitudinal range of Douglas fir is from about 20 to 30 inches, more than half of which falls in the "rainy season," from July to September. The winters are not severe, but there is heavy snowfall. The seasonal range of temperature is usually between the extremes of —10° and 95° F. The growing season is about six months long. Late frosts occasionally do much damage in this region.

According to Forest Service estimates, Douglas fir as a type forms nearly one-fourth of the forests in the northern Rocky Mountains, but decreases as it extends southward until in southern Arizona and New Mexico it averages less than 4 per cent of all the forest types. On the other hand, Douglas fir stumpage, irrespective of type, is a little more than a quarter of all stumpage in the north, while in the south it aggregates about 14 per cent.

PERMANENCE OF DOUGLAS FIR STANDS.

Both the pure and the mixed stands of Douglas fir in these regions may be either temporary or fairly permanent. Temporary stands usually result from the destruction of forests of shade-bearing species, followed by a reseeding of the soil by all species, when Douglas fir has an equal chance for light. Afterwards seedlings of the shade-bearing species come up underneath, while the more light-demanding Douglas fir undergrowth dies out. For instance, in the western hemlock forests of Washington and Oregon and in the Engelmann spruce and alpine fir forests of the Rocky Mountains, Douglas fir may be abundant in the first generation and almost unrepresented in the next.

Permanent stands result when conditions of light, soil, moisture, and temperature favor Douglas fir more than other trees. Altitude, exposure, and topography influence these conditions and result in changes in forest types. Douglas fir rarely grows in permanent stands in western Washington and Oregon, except where soil and moisture conditions are more favorable to it than to hemlock, arbor-vitæ, spruce, or the true firs. The Rocky Mountain form often grows in permanent stands with yellow pine and white fir.

Fires which have left a preponderance of Douglas fir seed trees, and have destroyed the humous layer, are often followed by dense, pure stands of Douglas fir. Their permanence is favored by the scarcity of seed trees of more tolerant species, but is jeopardized by density of crown cover and the humus formed by the dead twigs and leaves, which prevent the germination and growth of Douglas fir, but which favor shade-enduring trees.

SILVICAL CHARACTERISTICS AND REQUIREMENTS OF THE TWO FORMS.

Some of the differences between the two forms of Douglas fir have already been mentioned, but they also show more or less distinct differences in many of their silvical characteristics and requirements, and it is on a thorough knowledge of these that the intelligent management of the two forms must rest. Their respective soil requirements, tolerance of shade, reproductive characteristics, rate of growth, longevity, and susceptibility to damage from fire, wind, and frost, all have an important bearing on the treatment the two forms should receive.

SOIL AND MOISTURE.

Little difference exists between the two forms with respect to soil requirements. Throughout its range Douglas fir accommodates itself with facility to the character of the soil in the locality where it happens to strike root. But, other conditions being equal, it shows by

its form and rate of growth a decided preference for deep rather than shallow soils, and avoids dry, light sand, as well as heavy clays. It grows best on fresh sandy loam or loamy sand, and reaches its largest size on deep, porous, loamy soil, well watered and at the same time well drained.

On dry, sandy soils the characteristic associate of Douglas fir almost throughout its range is yellow pine. In southern Oregon and in California, Port Orford cedar on the coast and incense cedar in the mountains also share sandy soils with it. Where loamy ingredients prevail, the coast form of the tree mixes with Sitka spruce on fresh soils, while on dry soils in the Rocky Mountains and California white fir mixes with Douglas fir. In the northern Rocky Mountains Douglas fir gives way to lodgepole pine on coarse, fresh, gravelly soils, and to Engelmann spruce and alpine fir in poorly drained situations and clayey soils. It thrives in northern Montana and Idaho on the deep, fresh, porous loams on which western larch makes its best growth.

Douglas fir also adapts itself readily to varying conditions of moisture in soil and atmosphere. The coast form reaches its largest size in the heavily watered north coast region, and is scarcely smaller where it grows in the heavy fogs of the California Sierra Nevada. Here it makes its best growth in humid situations, associated with such moisture-loving species as western hemlock and giant arborvitæ. In southern Oregon it has been found growing at the edges of ocean inlets, where the least rise submerges its roots in brackish water. In dry situations its growth is slower and its size smaller than on fresh but well-drained soils. Atmospheric humidity is essential to its best height development, and in dry air with fluctuating moisture content it does not equal, even on the best soils, the height it attains on the poorest soils in humid regions.

The Rocky Mountain form is much less susceptible to injury from drought than the coast form. It grows best, however, on cool northerly slopes and in protected canyons at fairly high altitudes. Such situations afford the greatest degree of atmospheric humidity and the most soil moisture. On slopes fully exposed to the sun, both soil and air moisture are scant, and Douglas fir is proportionately stunted and knotty. In the lodgepole pine type of forest, it gives place to the pine in moist situations, but is able to succeed the pine on dry soil.

Its adaptability to soil and moisture conditions often saves Douglas fir from exclusion by other aggressive species, more tolerant of shade, but also more exacting in regard to soil and moisture. In western Washington and Oregon, Sitka spruce, western hemlock, giant arborvitæ, and lowland and amabilis firs, which can all endure more shade, are able to monopolize the soils which best suit them, and tend to

displace Douglas fir. The Rocky Mountain Douglas fir, also, gives way to Engelmann spruce and alpine fir when it comes into conflict with these species for the best soils. Both forms of Douglas fir, when forced by other species from preferred situations, maintain themselves by their better ability to grow on poor soil until some accident to the monopolizing stand allows them to return.

TOLERANCE.

One of the most important considerations in the management of Douglas fir is its demand for light and its relation in this respect to associated species. The coast form is less tolerant than all its important associates except yellow pine, western larch, and noble fir. It maintains its supremacy in the forest of this region through its adaptability to varying conditions of soil and moisture and through its extraordinary aggressiveness in seeding down burns and other openings in the forest. In California and southern Oregon it is relatively tolerant as compared with the light-demanding species with which it associates; it is more tolerant than yellow and sugar pines and only slightly less so than incense cedar and white fir.

The mountain form is considerably less tolerant than its frequent associates, Engelmann spruce and alpine fir, and slightly less so than white fir, but will endure more shade than western larch, western yellow pine, lodgepole pine, and the piñions, junipers, and aspen. In the relatively light shade of mature lodgepole stands, Douglas fir reproduction makes better growth than that of the pine itself, and may, if suited by soil and moisture, outnumber the pine in the succeeding forest. Young lodgepole stands and the forests of the Engelmann spruce type, however, are too dense for successful Douglas fir reproduction.

Under heavy shade Douglas fir seedlings soon die out. With moderate overhead shade they maintain a slow, spindling growth for a number of years before they succumb. If released from shade after a few years' suppression they recover and make fair growth, but do not possess nearly so much vigor as trees grown from youth with plenty of overhead light. In ability to exist under shade and to recover from suppression, Douglas fir is outclassed in the Rocky Mountains by Engelmann spruce and alpine fir. In the coast region nearly all its associates show greater capacity in this respect.

Though it demands for its best growth an abundance of light, Douglas fir produces the tallest, straightest stems when well shaded from the side. Its branches are rather persistent, and remain on the stems long after the foliage has died from lack of light. If, however, these branches succumb to shading in early youth, as is the case when Douglas fir grows up in dense stands, they are broken from the trunk

at a short distance below the live crown and leave the mature stems clear for a long distance.

When it is given an equal chance with other species in the competition for light, Douglas fir grows rapidly, and on account of its large size usually assumes a dominant position in the stand. It makes its best growth under such conditions, since its relatively wide and deep root system allows it to compete successfully with the more shallow-rooted species among its associates. If the latter are tolerant species, however, such mixtures usually constitute only temporary types for Douglas fir, since, other conditions being equal, these more tolerant trees will be able to shade out the Douglas fir reproduction and exclude it from the ensuing stand.

REPRODUCTION.

The reproductive capacity of the several species is the most vital factor in determining the composition of a forest. Few western conifers outrank Douglas fir in abundance and vigor of reproduction. It begins to produce cones early, and continues to bear seed almost every year up to an advanced age. Under favorable soil and climatic conditions, a large proportion of the seed will germinate and produce seedlings. In some years seed production is much more abundant than in others. Just how often these heavy crops of seed are borne is not known with certainty, but it is probable that they come at fairly regular intervals of from three to five years, varying with the region and situation. Not infrequently many of the cones are barren.

In the coast region Douglas fir only 12 years old has been found bearing cones. In the Rocky Mountains the minimum cone-bearing age is recorded as 20 years. As a rule, however, the period of abundant cone production rarely begins, even in open-grown trees, before the fortieth or fiftieth year, and when the trees grow in partial shade it is retarded until a much later date. A full supply of light is essential for good seed production, and hence trees in dense stands do not bear so abundantly as open-grown trees, since only their top branches receive the requisite amount of light. Although Douglas fir continues to produce cones late in life, the abundance of production ultimately falls off, and extremely old trees bear very lightly.

The cones, which are borne on all parts of the crown and are not confined to the top, as in the true firs, may remain tightly closed for as much as three weeks after they become fully ripe. When they do open, the seeds, which are provided with large wings, are scattered by the wind and may be carried to a considerable distance from the seed tree, depending on the strength of the wind, the density of the forest, and the topography. The approximate radius of reproduction

from open-grown trees on level land is 100 or 200 yards; on exposed ridges and mountain slopes it may be much greater, and in closed stands and in narrow ravines much less. In marking timber over a rugged country, a judicious regard for the exposure and prevailing wind will enable a few seed trees to do the work which would otherwise require a large number.

Reproduction is, of course, apt to be most dense and even-aged near the mother trees, and to decrease in regularity and abundance with distance from the source of seed. With well-distributed seed trees a fully stocked second growth may often be established in one generation. When seed trees are scarce or poorly distributed, complete restocking may require two or three generations and result in an all-aged forest or in a mixture with other species, possibly worthless, which have come in in the meantime.

The seeds will germinate and produce seedlings, especially in the Rocky Mountain region, in mildly humous soils, but the most successful reproduction is to be found on fresh mineral soil. Almost any kind of mineral soil that contains a little moisture and is not too cold will afford a good seed bed. In good, deep, fresh, but well-drained soil the seedlings grow rapidly and are usually able to keep ahead of the competing species. Light is not an essential for germination, but becomes a very vital factor in the growth of the seedling as soon as the seed sprouts. Under moderate shade, such as that of mature lodgepole and white fir, the seedlings do not receive enough light for rapid growth, but are able to grow slowly for a long time. Aspen stands usually afford ideal protection and light conditions for good development.

One of the most striking silvical differences between the two forms of Douglas fir is their behavior in restocking burned-over areas. In the coast region dense stands of Douglas fir reproduction often cover extensive areas of burned land, and these result later in the homogeneous, even-aged fir forests typical of this region. Among the Rocky Mountains, on the other hand, large burns are rarely restocked with pure Douglas fir reproduction, and the proportion of other species in mixture is usually large. In the southern Rocky Mountains the scarcity of Douglas fir in the reproduction which comes in on burns is particularly striking. The principal causes for the smaller proportion of reproduction in the Rocky Mountain region probably are (1) the much less abundant seed supply, (2) the less hospitable soil conditions for germination, and (3) the presence of the aggressive lodgepole pine, which monopolizes burns to the exclusion of Douglas fir, just as the coast form of Douglas fir excludes western hemlock, giant arborvitæ, and Sitka spruce. Forest fires are the chief allies of lodgepole pine in its competition with Douglas fir. The thick,

resistant scales of lodgepole cones are efficient protection to the seeds from fires which are hot enough to kill the trees. In slashings and on standing trees the cones are opened by the heat from forest fires, and the seed thus released restocks the burn with even-aged lodgepole pine reproduction, often of great density. Douglas fir cones, on the contrary, are thin-scaled and inflammable. Its mature trees, however, resist fire better, and consequently fir seed trees may be the only survivors when the thin-barked, shallow-rooted lodgepole is destroyed. Under certain conditions, such as immaturity or scarcity of lodgepole cones at the time of the fire, this may result in the predominance of fir in the ensuing stand, but ordinarily lodgepole monopolizes the ground until the maturing stand admits enough light to permit a Douglas fir second growth.

The two forms differ also in that reproduction of the Rocky Mountain form is often found growing under the shade of the mature forest, while that of the coast form is practically restricted to clearings or to spaces under large openings in the crown cover. This is due partly to the more open nature of mature forests in the Rocky Mountains and partly to the less humous condition of the forest floor there.

The coast form of Douglas fir is handicapped in competition with western hemlock, arborvitæ, and Sitka spruce by its relatively low reproductive capacity on humous soil. In coast Douglas fir stands which contain a mixture of these species the destruction of the mature stand by insects, logging, or disease results almost inevitably in the absence of Douglas fir from the second growth, unless the mineral soil is exposed by fire or in lumbering. In very light thinnings of dense mixed stands, even ground burning is apt to prove ineffectual in reestablishing Douglas fir, since most of its associates, especially noble and lowland firs, germinate plentifully in the mineral soil, while all except noble fir outclass Douglas fir in ability to thrive in the shade of the remaining trees.

In the Rocky Mountains both Engelmann spruce and alpine fir will germinate and grow in mineral soil, and are better able than Douglas fir to grow in pure humus. Douglas fir reproduction is further handicapped in competition with these species by its comparative inability to endure shade, and when even-aged mixtures of spruce, alpine fir, and Douglas fir come in after burns the latter species rarely appears after the first generation.

Underbrush often grows sufficiently dense to exclude Douglas fir reproduction from situations in which it would otherwise flourish. This is especially the case in western Washington and Oregon, where salal and similar bushy growths sometimes cover the ground densely,

preventing the development of even the shade-enduring trees. The salal has a resinous foliage, however, and in dry seasons surface fires burn readily in it, leaving ideal seed-bed conditions for Douglas fir reproduction. In the southern Rocky Mountain region some kinds of undergrowth afford a much-needed protection from extremes of heat and cold, and seedlings thrive in their light shade. Light sod does not prevent the germination and growth of Douglas fir, though reproduction is slow on grassy areas. In some portions of its Rocky Mountain range it is gradually encroaching on the grass-covered mountain parks, some of which it promises eventually to reclaim.

The inability of Douglas fir to reproduce in dense shade or on very humous soils is an important factor in determining the management of the forests in which it grows. In the coast region, where it grows mixed with western hemlock and other tolerant species which germinate on leaf litter, the proportion of fir cut should be reduced to a minimum, while the thinnings of all other species should be heavy enough to admit abundant light. The brush should be piled and burned to expose the mineral soil, and, if it can be done safely, the surface should be burned over for the same purpose. To replace young stands of inferior species, such as lowland and noble firs and western hemlock, it may be advisable to destroy these species by burning, provided Douglas fir seed trees are present and there is a certainty of an abundant seed crop. In the Rocky Mountains, where other species more aggressive in restocking burns are present, the encouragement of Douglas fir by surface burning becomes hazardous. The ability of Douglas fir to germinate and grow in light humus and under moderate shade would suggest a thinning without surface burning or with brush piling and burning. Where the danger from windfall does not have to be considered, the heaviness of the thinning should depend on the proportion of Douglas fir seed trees in the stand.

SUSCEPTIBILITY TO INJURY.

Generally speaking, Douglas fir is less susceptible to the ordinary enemies of the forest than most of its associates. There are a number of influences, however, which are capable of working great damage to Douglas fir, both in natural and in planted forests. The chief inorganic enemies of Douglas fir are fire, wind, and frost.

FIRE.

Except in youth, Douglas fir is remarkably well able to withstand fire. The thin bark of the young stem, which is thickly set with resin blisters, changes with increasing age to a thick coat of fire-

resistant bark, while the inflammable crowns become separated from the ground by an ever-increasing clear length of stem. The roots are usually well below the surface, firmly embedded in mineral soil, and out of danger from fires which destroy the superficial-rooted hemlock, lodgepole pine, spruce, and balsams.

While fire may be one of the greatest benefits to Douglas fir reproduction by preparing a seed bed, it is also its greatest enemy when once the seedlings are established. Young plants of Douglas fir fall easy victims to fire. The thin, resinous bark and delicate foliage are easily damaged by excessive heat and make a good fuel for the spread of fires.

When they do not actually kill the trees, fires may be the indirect means of their destruction by weakening their power of resistance and by subjecting them to other enemies. By burning away the bark and exposing the wood, fire becomes an agent in introducing destructive insects and fungi. Several insects which infest the roots and lower trunk, together with the common fungous disease called "butt rot" (*Polyporus schweinitzii*), are probably very frequently introduced in this way.

WIND.

The coast form of Douglas fir is quite subject to windfall, especially when individual trees are left isolated by thinning dense stands. This damage is greatly increased by persistent ground fires, which may smoulder in the débris around the base of the trunk until most of the roots are killed, or the trunk itself so hollowed that it will break before the first strong wind.

Besides the damage from windfall, Douglas fir suffers from internal injury by windshake. This is especially prevalent in Arizona and New Mexico, but occurs only in the older timber. It does not menace the life of a tree, except indirectly by preparing a way for the entrance of fungi and a ready path for the disease to spread along the cracks. Windshake often extends far toward the top of the tree and causes serious depreciation in the merchantable quality of the timber.

FROST.

The two forms of Douglas fir suffer to a varying degree from frost. In very frosty localities with poor drainage, such as the bottoms of narrow ravines and box canyons, both forms are susceptible to damage from late frosts, especially in early youth, but the coast form is much more likely to be damaged by early frosts, owing to the tenderness of its fall shoot. Growth in height is undoubtedly often retarded by the killing back of the tender spring growth, and young

plants are sometimes observed in frosty localities with every twig tipped with a dead spring shoot. Cold snaps occurring in the spring shortly after growth has begun occasionally damage old and young stock by killing back the tender shoots, and thus impede the year's growth. Observations made in the Capitan Mountains, New Mexico, indicate that Douglas fir is damaged less by late frost than limber, yellow, and piñon pines and white fir.

In German plantations, where both forms are grown side by side, the foliage of the coast fir is found to suffer considerably from severe winter temperatures, especially when the aspect is southerly. The needles on the south sides of the plants turn bright red and drop off the next spring. This weakness is entirely unknown in the mountain form, whose needles are well protected by a waxy cuticle from excessive winter transpiration.

In European plantations the mountain form, coming from a climate characterized by severe winters and dry summers, for a time promised by virtue of its greater hardiness to supersede the coast fir. This, however, it has failed to do, owing to the fact that, although coast fir is less frost-hardy, it is not sufficiently so to prevent its growth in many situations, or to counterbalance its superiority in the matter of rapidity of growth. In the United States, cultural experiments in the Northeast with the coast fir have hitherto yielded poor results, because it has not been able to withstand the eastern climate. The mountain fir, on the other hand, has in some localities made slow but fairly persistent growth since its introduction in 1863.

In the northern Rocky Mountains Douglas fir is often damaged by frost cracks, or "gum checks," which are longitudinal splits in the trunks, caused by the unequal contraction of the inner and outer parts of the stem under the influence of sudden and extreme cold. Frost cracks usually become partially or wholly filled with pitch, when they present an easy access for fire into the trunk and up to the crown. They also open the way for insects and fungi, and trees which show frost cracks should therefore be removed, if practicable, whenever they are met with in timber marking. A "gum check" is a bad defect in a log, especially if it is spiral.

In the Rocky Mountains, Douglas fir seedlings frequently fall prey to drought, which is a potent factor in restricting its lower altitudinal range.

Douglas fir is very easily killed by sulphur fumes from smelters, and is more susceptible to damage from this source than lodgepole pine. In the vicinity of Anaconda, Mont., the radius of damage from smelter fumes is from 10 to 12 miles.

LONGEVITY.

The giant Douglas firs of the coast forest are known to have attained great age. More than 700 rings have been counted on a single stump. The vast majority of trees, however, succumb to fire, windfall, insects, or fungous diseases at a much earlier age. The average length of life of the merchantable stand has not been determined, but it is safe to say that in the coast region the larger trees have taken upward of four hundred years to attain their present size. The Rocky Mountain forest contains relatively few trees more than 400 years old. By the end of the second century diameter growth is very slow and height growth has practically ceased, and from that point on the tree continues to grow very slowly until it falls a victim to the numerous destructive agencies that surround it.

SIZE.

Closely related to longevity is the maximum size attained by the trees. The tallest Douglas fir of the coast form for which there is record was 380 feet high, which is also the maximum height recorded for redwood. Trees 15 feet in diameter have been observed, and some of the largest Douglas firs of the coast forest have scaled as much as 60,000 board feet. Whole forests are found in which the trees average 250 feet in height and 5 feet in diameter. Such trees are usually clear for a long way up the stem, since their rapid growth in competition for light does not permit the formation of large side branches, and such small ones as are formed soon die under the shade of the crowns and are broken off.

In striking contrast to the enormous dimensions of the coast fir are the relatively small sizes of the mature mountain form. Even under exceptionally favorable conditions this form rarely exceeds 150 feet in height or 4 feet in diameter. In the northern and central Rocky Mountains, and under conditions of altitude and exposure in which it attains its best development, it reaches an average height of from 100 to 120 feet, with a diameter of from 15 to 30 inches, at an age of 200 to 300 years. In the Gila, Datil, and Magdalena National Forests, New Mexico, it reaches a merchantable diameter of 18 inches at breastheight in from 100 to 150 years, and trees 150 feet high have been reported. At the upper altitudinal limit of its merchantable range in Colorado and Utah it remains for the most part below 70 feet in height, with a breasthigh diameter of about 27 inches. Its trunk maintains a pronounced taper from the stump up, and a tree of these dimensions would not cut over 480 board feet (Scribner rule). In contrast to this, a coast fir of the same diameter would be from 145 to 170 feet tall and would yield from 1,000 to 1,250 board feet, while

a coast fir 70 feet high would measure only 9 inches in diameter and would yield but 50 board feet. In pure forests the Rocky Mountain form does not produce such dense stands nor clean, straight boles as the coast fir, but because of its slower growth it forms for a given average diameter a much more open and stunted stand, and for a given age a forest of much smaller trees than does the coast fir.

RATE OF GROWTH.

The coast form greatly exceeds the mountain form in rapidity of height growth. In Europe it has exhibited a more rapid growth in favorable situations than any of the native coniferous timber trees. It attains this rapidity both by the actual rate at which it grows and by the long duration of the growth period, due to its characteristic of putting out a second "leader," or terminal shoot, in the fall, after the growth of the mountain form has ceased for the year. The susceptibility of the unripened green shoots to early frosts, which in exposed situations are very apt to kill back this portion of the growth, has led to a considerable difference of opinion among the European foresters who advocate the extensive planting of Douglas fir as to whether the rapid-growing coast form or the slow-growing but more hardy Rocky Mountain form should be used. The consensus of opinion now seems to be in favor of the former, since in protected situations it is able to resist all but the most severe European conditions, and its other qualities place it far in the lead of the mountain form.

The table of height and diameter growth here given illustrates the difference in rate of growth between the two forms when they grow in virgin forests. They are averages read from curves, and were obtained from ring counts along the average diameters of the stumps and the ends of the logs of mature felled trees. Diameters are at breastheight except those for western Washington, which are at stump height. On account of the height to which stumps are cut in this region, these figures are comparable to breastheight measurements in other regions. The figures showing height growth in the Targhee National Forest represent only partial analyses; that is, they were derived from stump counts of the total age combined with measurements of the total heights of the trees. The measurements on the Uinta National Forest represent average conditions, and were taken from merchantable trees grown under optimum conditions, as well as in second-class situations. The figures from the San Juan National Forest are from merchantable trees in a mixed stand of Douglas fir, Engelmann spruce, and alpine fir near the upper altitudinal limit of Douglas fir at an elevation of 10,300 feet.

Height and diameter growth of Douglas fir.

Age.	Height growth.				Diameter growth.			
	Coast form.	Mountain form.			Coast form.	Mountain form.		
	Western Washington.[a]	Targhee.[b]	Uinta.[c]	San Juan.[c]	Western Washington.[a]	Targhee.[b]	Uinta.[c]	San Juan.[c]
Years.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
10	8	.....	1	0.8	.....	.....	.....	.....
20	25	.....	3	1.8	4.0	.....	.....	.....
30	48	.....	5	3.5	7.5	1.6	0.2	.....
40	64	.....	9	5.5	10.6	3.5	1.6	0.5
50	80	.....	14	9	13.7	5.9	3.3	1.4
60	93	.....	20	13	16.2	8.3	5.2	2.4
70	106	54	28	17	18.4	10.5	6.9	3.5
80	118	59	36	21	20.5	12.3	8.6	4.4
90	128	65	43	27	22.5	14.0	10.0	5.3
100	138	70	51	32	24.3	15.6	11.3	6.2
110	148	75	58	37	26.0	17.0	12.4	7.2
120	157	79	64	41	27.4	18.2	13.4	8.1
130	165	83	69	45	28.7	19.3	14.4	9.0
140	173	86	73	48	30.0	20.3	15.2	9.9
150	180	89	75	50	31.3	21.1	16.1	10.7
160	186	91	77	52	32.6	21.9	16.9	11.4
170	192	95	78	53	33.8	22.7	17.8	12.1
180	198	95	79	54	35.0	23.5	18.7	12.8
190	204	96	80	55	36.2	24.2	19.6	13.4
200	209	97	.....	56	37.4	24.9	20.6	14.0
210	213	97	.....	56	38.4	.....	.....	14.6
220	217	98	.....	57	39.5	.....	.....	15.3
230	221	98	.....	57	40.6	.....	.....	15.9
240	225	98	.....	.....	41.6	.....	.....	.....
250	228	98	.....	.....	42.6	.....	.....	.....
260	231	99	.....	.....	43.6	.....	.....	.....
270	234	99	.....	.....	44.6	.....	.....	.....
280	236	99	.....	.....	45.6	.....	.....	.....
290	238	99	.....	.....	46.5	.....	.....	.....
300	240	99	.....	.....	47.4	.....	.....	.....

[a] Washington figures from Forest Service Bulletin No. 33, "The Western Hemlock," 1899, by E. T. Allen.

[b] Targhee figures from Henry's Lake Working Plan, 1906, by J. G. Peters and A. T. Boisen.

[c] Uinta and San Juan figures from analyses by E. H. Frothingham on the Uinta and San Juan National Forests, 1907.

It is important to note that these figures are entirely too few to be representative for large areas. They are of value, however, to illustrate in a general way the immense differences in rate of growth and size which exist between the coast and mountain forms of Douglas fir. Thus, at the age of 70 years the mountain form in the Targhee National Forest is only half as high and has only five-ninths as great a diameter as the coast form in western Washington, while at 300 years it remains less than half as high and has practically ceased its height growth, though the coast form is still growing at the rate of 2 feet in ten years. The figures for the San Juan National Forest show that at high altitudes in the Rocky Mountains Douglas fir requires 230 years to reach a size which the coast form in western Washington attains in less than 60 years.

When the coast form of Douglas fir comes up in crowded, even-aged stands, as it often does on burns, the trees make a rapid growth

in height at the expense of diameter. Diameter growth is greater in more open stands, owing to lessened competition for soil moisture as well as light. No experiments to determine the effect of thinnings on growth rate have been made, but it is probable that judicious thinnings made from time to time in crowded stands would result in increased growth, both in diameter and in height.

MANAGEMENT.

No hard and fast rules can be formulated for the management of Douglas fir in any of its silvical regions. A few broad rules can, however, be outlined for each of these extended regions, which, though lacking in detail, will suit the general conditions prevailing over the whole region, and can, by modification, be used as a basis for more detailed silviculture on limited areas.

The universal aim of silviculture is to get the most and the best timber per unit area in the shortest possible time. On the humid mountain slopes of Washington and Oregon no tree is better fitted to achieve this ideal than Douglas fir. Its rapid growth, the density of its stands, and the high quality of its lumber give it preference in suitable situations over all other species. Besides this it reproduecs itself abundantly, and a second crop is relatively easy to secure. In the southern parts of its range, however, other trees often excel it in value, and in such cases the object of management must be to reduce the proportion of fir and encourage a predominance of the more valuable species.

The successful silvicultural management of a virgin forest should result in a complete and even restocking of cut-over areas with young growth of the best species which the situation is capable of producing. In practice this result is sought by rules planned to secure a suitable seed bed for the desired species and an abundant supply of the right kind of seed. Since Douglas fir needs mineral soil to germinate and requires plenty of light afterwards, the first object is achieved for this tree by clean cutting or by thinning heavily enough to admit an abundance of light, and by burning away the humous layer which covers the mineral soil. To insure a sufficient seed supply, enough trees must be left on each acre of ground to scatter seed evenly over all parts of it. The manner of thinning, disposal of brush, and the number and distribution of seed trees are details which vary with the different silvical regions in the range of Douglas fir and with local conditions in each.

NORTH COAST REGION.

In the forests of western Washington and Oregon, where Douglas fir is by far the most abundant tree and often forms vast, nearly pure, even-aged stands, its management is comparatively simple. The chief

problem connected with this forest is to prevent more tolerant species, especially western hemlock, from growing up under Douglas fir and gradually securing permanent possession of the ground. The best solution to this problem will usually be to cut clean and burn over the surface. Douglas fir reproduction will thus find abundant light and a mineral soil, and by its prolific seed production and the density and rapid growth of the young stand may reasonably be expected to exclude from the stand even the more tolerant reproduction of hemlock, arborvitæ, or spruce. Since at maturity such even-aged stands of Douglas fir are apt to run quite uniformly above the minimum merchantable diameter limit, clean cutting is justified from a commercial standpoint. The mineral soil exposed by ground burning also affords an excellent seed bed for noble fir and western white pine, desirable associates of Douglas fir, and in some localities this encouragement may be advantageous.

Clean cutting to the lowest merchantable diameter limit should, then, be the general plan for the greater part of this type of forest, except on steep slopes with shallow soil. On steep slopes and ridges the forest should usually be held intact, since the trees are apt to be shorter and knotty and, therefore, of inferior commercial value, but they are of the greatest value as sources of seed for restocking the adjoining cuttings. Great care must be exercised to leave only firmly rooted specimens for seed trees after dense stands are logged, since isolated trees in such situations are particularly subject to windfall. In some situations they should be left in groups, to afford each other mutual protection during the period necessary for establishing reproduction. Trees growing in the more open parts of the stand are usually shorter, knottier, and more wind-firm than those in the denser portions, and are therefore more desirable for seed trees than for logs.

Where the forest is not pure Douglas fir, but contains a considerable proportion of hemlock, cedar, spruce, or balsam, the cuttings should aim, in localities suitable for Douglas fir, to remove all merchantable timber of each species except enough Douglas fir seed trees to insure an abundant reproduction. The surface should then be burned over to remove the forest litter and humus, and to expose the mineral soil. In this type of forest, heavy cuttings are necessary for the successful reproduction of Douglas fir on account of the great density of the stands and the heavy accumulations of forest litter which are characteristic of them. Except in very heavy thinnings, amounting practically to clean cutting, surface burning can not be practiced without great danger to the remaining trees, but when the mature stand is removed the surface may, with due precautions, be

safely burned over. The reproduction of more tolerant species which existed under the shade of the high forest will thus be removed from competition, and at the same time a suitable seed bed will be prepared for the desired Douglas fir reproduction. A few years ago the poor demand for hemlock, cedar, and other less valuable associates of Douglas fir would have precluded such a method of treatment, but with the increase in demand for these species, which is already beginning to be felt, there is no doubt that it may be applied with commercial as well as silvicultural success.

In the humid portions of this region, especially in the "fog belt" along the coast, surface burning is impracticable during the wet season, when the heavy rains which fall almost every day keep the brush soaked with water and practically fireproof. On the other hand, burning should never be done in the dry season after the slash has had time to dry out thoroughly. During this season the dead branches become tinder-like and inflammable, and even the greatest care may be insufficient to prevent surface fires from spreading to the adjacent stand and becoming destructive crown fires. A time should be chosen for the burning when the brush is dry enough to burn well, but not so dry as to cause a hot fire which can be controlled only with difficulty.

The burning should be conducted by a force of men sufficiently large to prevent all danger from the fire spreading to the adjacent uncut areas. It should be done by blocks or compartments, varying in size with the character of the topography and the dryness of the slash, and laid out so far as possible with ridges and streams for boundaries. Where no natural boundaries exist the burning areas will often have to be separated by fire lanes, 50 to 75 feet wide, from which the brush has been cleared and piled back on the area to be burned. In the dense undergrowth to be found in the "fog belt," where lanes of this width could ordinarily be constructed only at a prohibitive cost, skid roads can often be utilized for fire lanes. By starting the fires along the skid roads and allowing them to burn inward toward the center of a burning area, the slash fires can, with due precautions, be effectually controlled.

Each area should be burned separately, and fire on the second should not be started until that on the first is thoroughly extinguished. The tops should be lopped and scattered evenly over the surface, but not within 20 feet of remaining trees. A trench should be dug around each tree left for seed, deep enough to prevent fire from creeping through the humus and killing the tree. This trench should be at least 15 feet from the tree.

SIERRA REGION.

Sugar pine and yellow pine are more valuable than Douglas fir in this region, and consequently Douglas fir should be cut close and a preponderance of sugar and yellow pine seed trees should be left. The pine seedlings, which are much less tolerant than Douglas fir, make good growth in the increased light afforded by the thinnings, and can then cope on equal terms with the fir. Where, as is commonly the case near streams at the lower elevations, Douglas fir keeps to the gulches and pine to the ridges, heavy thinning of the fir and retention of all the pines necessary for seed at the tops of the slopes will tend to increase the proportion of the pines. Since pine cones require two years to mature and those of Douglas fir but one, the probability of a good seed crop can be estimated farther in advance for the pines than for Douglas fir. Cuttings can, therefore, be planned which will be immediately followed by a heavy fall of pine seed, and the chances for a good stand of pine reproduction increased. The number of pine seed trees may be reduced in anticipation of such a seed year, while in years of scant seed production a proportionately greater number should be left to insure an immediate restocking.

White fir and incense cedar are generally of less value than Douglas fir, but are at the same time more tolerant of shade. When they grow in mixture with Douglas fir they should therefore be cut to the lowest possible diameter limits, while the cutting of the more valuable sugar and yellow pines and Douglas fir should be restricted to a higher minimum diameter.

NORTHERN ROCKY MOUNTAIN REGION.

This region is characterized by a multiplicity of forest types and subtypes. The different conditions of these types call for distinct methods of management, and silvicultural rules are not so widely applicable as in the preceding type.

The more valuable species in this forest which are to be favored in management are western white pine, Douglas fir, western larch, western yellow pine, Engelmann spruce, and giant arborvitæ. The other species of this region are of less commercial value, and should be discriminated against in marking for cutting wherever they grow in mixture with the better species. Lowland fir and western hemlock are especially undesirable in mixture with Douglas fir, owing to their greater tolerance of shade and consequent ability to drive out the Douglas fir. Lowland fir generally grows more rapidly, at least in youth, than the Douglas fir of this region, and on situations favorable to both is always a menace to the latter species. Where it predominates in the stand, the less tolerant white pine, Douglas fir, and

larch are saved from exclusion only by the short life of the lowland fir, which is quite susceptible to disease. Plans for the future forest which contemplate cutting the second growth at a period less than the average life of lowland fir must take into consideration the aggressiveness of this species.

Since both white pine and Douglas fir are active in restocking burns, a heavy thinning followed by a light surface fire, immediately preceding a good seed year of these species, is advisable wherever there is no need of keeping the stand intact for protective purposes. Where heavy thinnings can not be practiced, reduction of the preponderance of seed trees of undesirable species must be accomplished gradually by successive cuttings in which the preferred species are favored by high cutting limits, while the others are cut to the lowest merchantable diameters. Such management must necessarily be gradual on account of the unwillingness of purchasers to take a large proportion of the poorer grades.

CENTRAL ROCKY MOUNTAIN REGION.

The value of Douglas fir for mining and flume timbers renders it the species to be encouraged above all others in this region. It grows here chiefly in mixture, and competes, according to situation, with lodgepole pine and yellow pine. In both cases the selection method of cutting is likely to increase the proportion of Douglas fir.

The dense, pure stands of lodgepole pine which characterize this region are peculiarly adapted to clean cutting in strips, with surface burning to provide a mineral seed bed. Where Douglas fir mixes with lodgepole pine in sufficient abundance and quality to warrant its perpetuation as a type, selection cuttings should be conducted with a view to removing a maximum of the pine and a minimum of the fir. The former should be thinned to the maximum amount consistent with security of the remaining stand against windfall, while the latter should be cut only to a relatively high diameter limit, so as to retain a reserve of seed trees sufficient to establish an even and abundant second growth throughout the thinned forest. The fact that Douglas fir is often found in nature coming up under mature stands of lodgepole pine indicates that the mountain form of Douglas fir is sufficiently tolerant to grow in light shade, and further, that the humous soil conditions of such stands afford a satisfactory seed bed for the fir without the ground burning so essential for the best reproduction of lodgepole pine. For protection against fire it will probably be necessary to pile and burn the brush resulting from logging, but to prevent exposing mineral soil—the best seed bed for lodgepole pine—such burning should be restricted to the smallest pos-

sible area. Thinnings of this nature at times when abundant young cones promise a sure crop of Douglas fir seed should result in a thrifty stand of fir reproduction.

Owing to its comparative tolerance of shade, the management of Douglas fir in yellow pine stands is fairly simple. Where Douglas fir is to be encouraged it should be favored by marking to larger minimum limits than yellow pine, but enough of the latter should be left to afford light shade for the fir seedlings. Brush burning may be practiced with due precautions to prevent forest fires, since in this zone no active competition from lodgepole pine is to be feared.

Throughout this region, as in all others, the encouragement of Douglas fir should not be attempted in situations which are manifestly better adapted to other species. The dry soils at lower altitudes are especially fitted for yellow pine, and attempts to force fir into such situations will result in scrubby timber, very inferior to the pine which grows there naturally. In like manner, situations best fitted for lodgepole pine forests should be managed as such. The middle ground, where Douglas fir flourishes naturally, may often be extended somewhat into the lodgepole pine type on the one hand and the yellow pine type on the other; but further attempt to supplant either of these species with Douglas fir is hazardous.

SOUTHERN ROCKY MOUNTAIN REGION.

In the southern part of the Rocky Mountain region yellow pine assumes chief importance in the commercial forest. Douglas fir is neither as abundant nor as valuable as in the northern States. When it grows in mixture with yellow pine the latter should be favored in management, except in mining regions, where Douglas fir timber is in demand for props, stulls, and lagging, on account of its greater durability. Next to yellow pine, however, Douglas fir should be given preference in the management of mixed forests; and white fir, Mexican white pine, and other less important trees which compete with it should be discriminated against.

In this region a soil cover of brush is beneficial, and is often absolutely necessary to secure a satisfactory stand of reproduction. So injurious to young seedlings is the drying effect of the summer sun that it forms one of the principal enemies of reproduction in the drier parts of this region. In many places seedlings are to be found only under the cover of brush, where the soil is protected from complete desiccation. Brush piles also afford some protection against damage from stock, which is also an important enemy to reproduction. It is therefore inadvisable to burn brush in this region except where the fire danger is especially great. The brush should be loosely massed in isolated piles at a distance of at least 10 feet from seed trees.

Above the yellow pine zone, fires, except in the drier portions of this region, are usually followed by dense, pure stands of aspen, which often cover whole watersheds with an even-aged forest of light-foliaged trees. In the shade of aspen thickets Douglas fir, together with white fir and, at high altitudes, alpine fir and Engelmann spruce, finds excellent conditions for reproduction. In the lower part of the spruce belt a thrifty but slow-growing reproduction of Engelmann spruce, alpine fir, and Douglas fir may often be found under aspen cover on old burns. On account of its rapid growth, aspen only a year or two older than the coniferous reproduction may be ten times as high, and the more tardy spruce and firs may receive the benefit of its shade until they are 50 feet tall and as many years old. From that time on the aspen ceases to be a factor in the forest. As a rule, therefore, aspen is not to be considered a forest weed, and its value as a nurse crop for the future stand should not be underestimated. Owing to the optimum conditions which aspen stands, when not too dense, offer for the development of Douglas fir, they are to be recommended as planting sites for this species, especially on southerly slopes and in regions characterized by extremes of temperature.

CONCLUSIONS.

A careful study of Douglas fir leaves no doubt that, at least from a silvicultural point of view, there are two forms of Douglas fir, one of which inhabits the region between the Cascades and Sierra Nevada and the coast, while the other grows throughout the Rocky Mountain region. Proof of this variation is to be found in the results of extensive cultural experiments in Germany, France, and England, in morphological differences in the fir throughout its range, and especially in the varying silvical requirements of the species and the immensely different conditions of environment to which it is subjected in different regions. The actual relationship between the two forms is probably that of climatic varieties, although some authorities consider them distinct species and others botanical varieties.

As a general rule, subject to local modification, Douglas fir is best managed in western Washington and Oregon by clean cutting and surface burning, and in the northern and central Rocky Mountains by selection cutting with brush piling and burning. In California and in the southern Rocky Mountains it is neither the most nor the least valuable tree, and should be discriminated against in the yellow pine zone and favored in competition with other species. Its hardiness and the high value of its timber render it especially fitted for planting, particularly in mining regions. Excellent conditions for planting are to be found under the light shade of aspen stands, particularly in the southern Rockies.

Because of its exceptional commercial and silvicultural value, Douglas fir bids fair to become the most widely cultivated of the western conifers. In forest planting it should be remembered that the coast form is superior to the mountain form in almost every respect, and except for ornamental purposes, or for regions where the climate is unfavorable to the growth of the coast form, seed from the Rocky Mountains should never be selected. In Great Britain and in Germany the coast form has been grown with success; in the northeastern United States and in alpine situations in Europe the Rocky Mountain form is apparently better able to succeed. In every case great care should be taken, in selecting seed, to choose that from rapid-growing, straight, symmetrical trees.

Approved:

JAMES WILSON,
Secretary.

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